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BULLETIN No. LXIV

THE SMELTS (OSMERIDAE) OF BRITISH COLUMBIA

BY

JOHN LAWSON HART

AND

J. LAURENCE McHUGH

Pacific Biological Station

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THE SMELTS (OSMERIDAE) OF BRITISH COLUMBIA

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INTRODUCTION

Four kinds of smelts are found in British Columbia: the eulachon (*Thaleichthys pacificus*), the silver smelt (*Hypomesus pretiosus*), the capelin (*Mallotus catervarius*), and the long-finned smelt (*Spirinchus dilatus*). All differ from other British Columbia coastwise fish, except the salmons, in being small silvery fish with adipose fins and no barbels. They differ from the salmons in having no fleshy flap at the base of the pelvic fin (fig. 2), in having the lower jaw longer than the upper, and in having, in general, smaller heads, more slender bodies, and less prominent pigment patterns. The smelts are confined to arctic and north temperate waters and are best represented in the north Pacific basin. All spawn in fresh water or along the seashore. The sexes can be readily distinguished at spawning time by differences in body form, colour, skin surface, etc.

Most of the technical terms to be used in the text are illustrated in figure 2. A few of the others are explained below.

The scales of smelts carry fine concentric ridges called *circuli*, which appear as lines when the scales are viewed under a microscope.

Periods of retarded growth caused by winter conditions sometimes produce recognizable annual rings on scales and flat bones of fishes and these are called *annuli*. In the scales of smelts an *annulus* may be recognized only by the occurrence of a large number of broken circuli in its vicinity (fig. 5).

Guanin, a substance belonging to the so-called purine group, occurs as fine crystals in the skin of fish and is responsible for the silvery appearance of many species.

In most fishes one or more small bones called *otoliths* lie unattached to any others, in a sac in the middle ear. They are supposed to be related to the sense of equilibrium, and frequently show annuli.

$S(x - \bar{x})^2$ indicates the statistical "variance", a value used by the statistically inclined in judging the dependability of an average.

When a fish with an adipose fin and no barbels (i.e. not a catfish) and no fleshy flap above the base of the pelvic fin (i.e. not a salmon) is encountered in coastwise British Columbia, it may be identified by the following key:

A. Scales small with about 150 rows in length of fish; 16 to 20 supporting bony rays in pectoral fin; relatively large adipose fin:

CAPELIN—*Mallotus catervarius*

Bull. Fish. Res. Bd. Can. LXIV (1944)

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AA. Scales of moderate size, with fewer than 85 rows in length of fish; 15 or fewer supporting bony rays in pectoral fin; adipose fin, small or moderate: see B. or BB.

B. Mouth small, with maxillary not reaching mid-point of pupil of eye; dorsal fin origin slightly in front of origin of pelvic fins:

SILVER SMELT—*Hypomesus pretiosus*

BB. Mouth larger, with maxillary extending beyond mid-point of pupil; dorsal fin origin distinctly behind origin of pelvic fins: see C. or CC.

C. Fine striae on bones of operculum paralleling ventral and posterior margins; pectoral fin distinctly shorter than head:

EULACHON—*Thaleichthys pacificus*

CC. No such striae on bones of operculum; pectoral fins as long or longer than head:

LONG-FINNED SMELT—*Spirinchus dilatus*

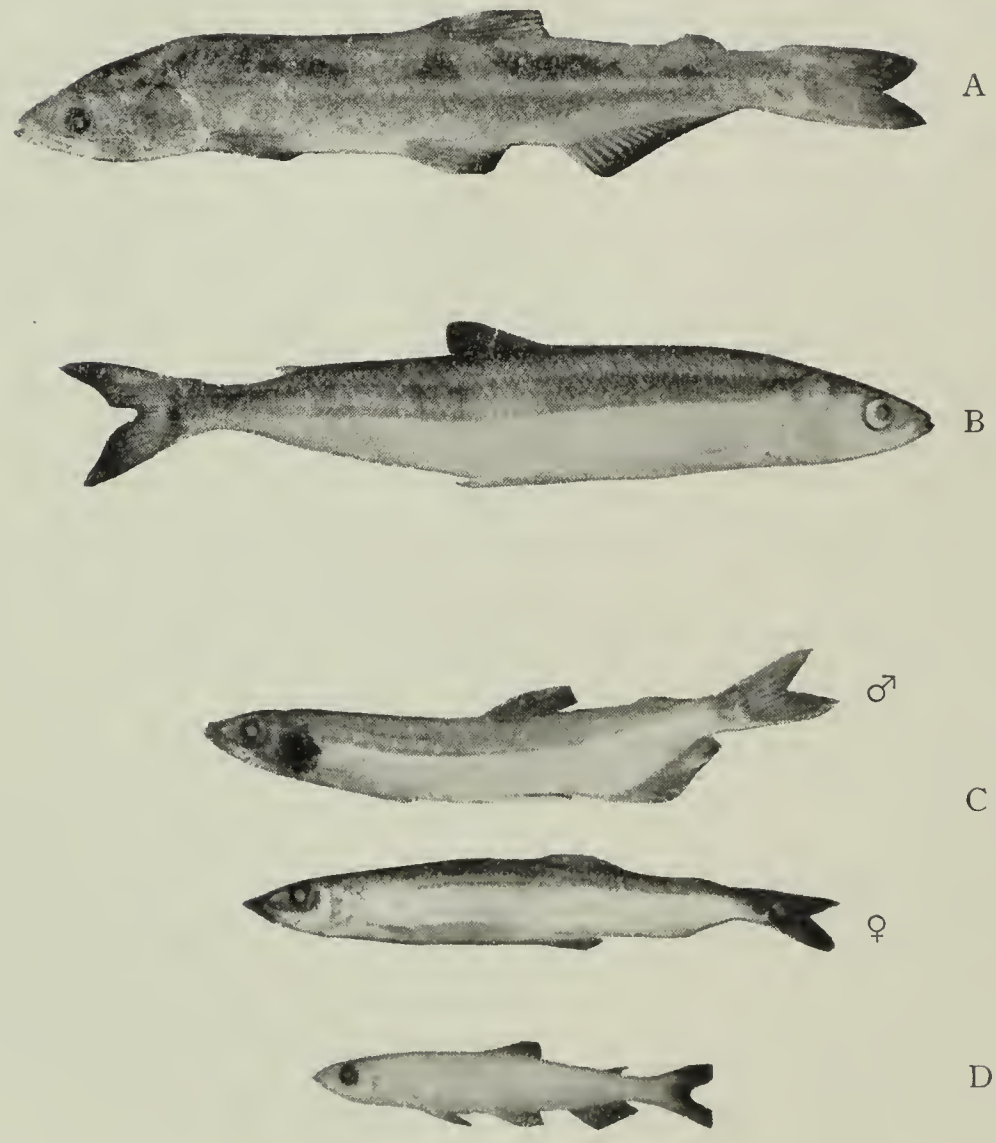

FIGURE 1. British Columbia smelts. A. Spawning Fraser river male eulachon. B. Adult silver smelt. C. Spawning capelin; ♂ male; ♀ female. D. Young long-finned smelt. Fraser river.

NAMES

The name "eulachon" is derived from the Chinook, and has many variations, among them being the following: hoolakan, hooligan, hoolikan, olachan, ollachan, oolachan, oolichan, oulachan, oulachon oulacon, ulchen, ulichan, uthlecan, yshuh. It has been called candlefish because the flesh is so oily that the dried fish, when provided with a wick of rush-pith or strip from the inner bark of the cedar, burns with a steady flame, and was used as a candle by the natives. The Indians of the lower Fraser give it the name "swavie", or "chucka" —old woman. "Small fish" and "salvation fish" are the English equivalents of other Indian names. They have also been called "fathom fish" because strung on threads in their dried condition, they were sold by the fathom. The first part of the scientific name, *Thaleichthys pacificus* (Girard), also refers to the oily nature of the flesh (rich fish).

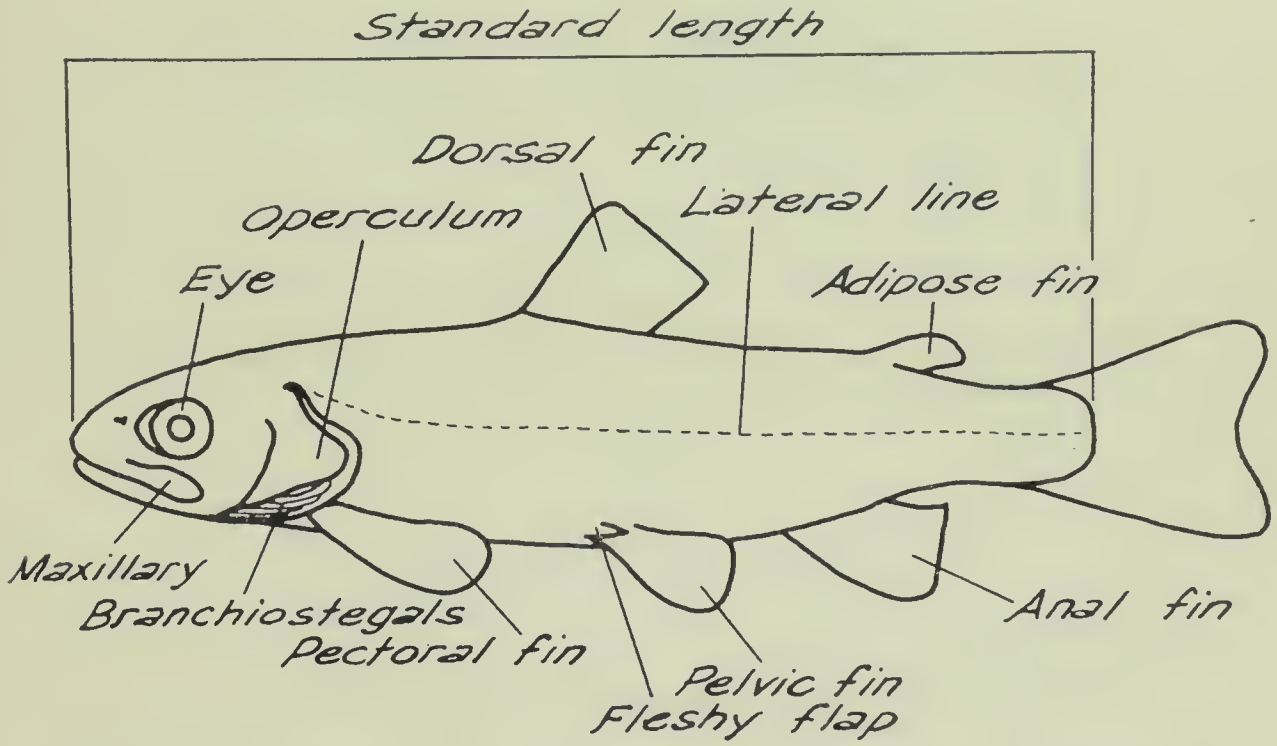

FIGURE 2. Young trout. Illustrating the body parts referred to in the text.

DESCRIPTION

The eulachon (figs. 1A, 3 and 4) has a large mouth, the maxillary bone extending to behind the pupil of the eye. The mouth is supplied with a number of moderately developed canine teeth, which are lost with the approach of sexual maturity so that the fish in the spawning run usually have no teeth at all.

At spawning time the males are easily distinguished from the females by having (1) tubercles on the scales (fig. 5A), particularly in the region of the lateral line, also on parts of the head; (2) the muscles of the body wall considerably more developed (fig. 6), making the whole fish more rigid; and (3) paired

fins definitely longer (pectoral; male 15.8% of the standard length, female 14.3%: pelvic; male 17.6%, female 14.3%). Also, as has been found in some other fishes, the females tend to have more abdominal vertebrae (their character shown in fig. 7) than the males, as though in adaptation to carry more eggs. In 1939 samples of eulachon from the Fraser river—the only ones for which the data are available—the difference in numbers of vertebrae between males and females is confined entirely to the abdominal region, as follows:

	Males	Females	Difference
Average total count	67.79	67.96	+ 0.17
Average abdominal count	39.63	39.82	+ 0.19
Average caudal count	28.16	28.14	− 0.02

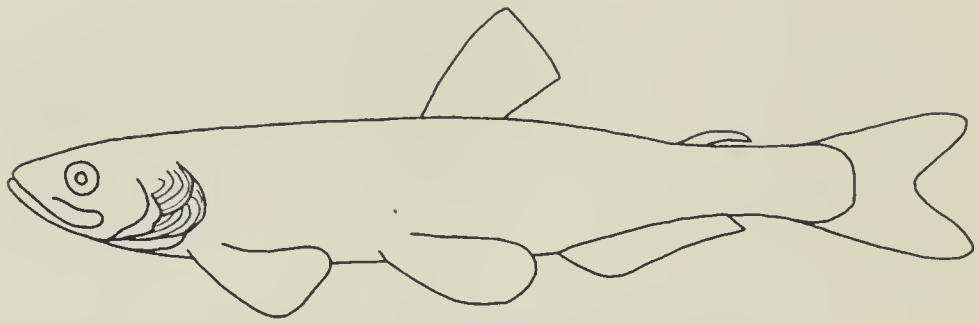

FIGURE 3. Male eulachon. Note large mouth; fine, concentric lines on opercular bones; sickle-shaped adipose fin.

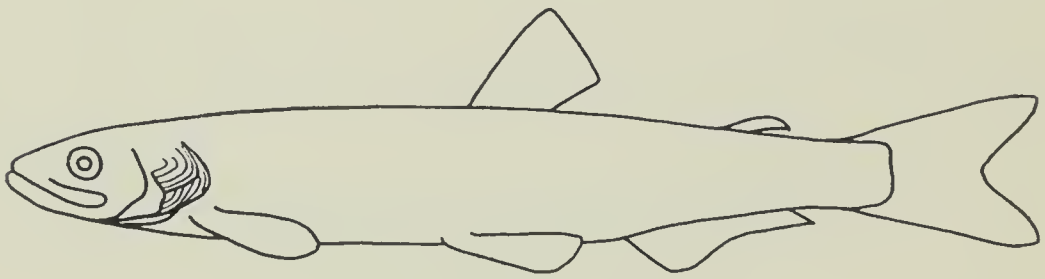

FIGURE 4. Female eulachon. Note more tapered form than in male and smaller fins.

DISTRIBUTION

Eulachon are found from northern California to the Bering sea. In British Columbia they enter all of the larger mainland rivers and some of the smaller streams on their spawning migration. It has not been possible to confirm the existence, either past or present, of a spawning run of these fish in Barkley sound on the west coast of Vancouver island as mentioned in an early report on British Columbia fisheries.

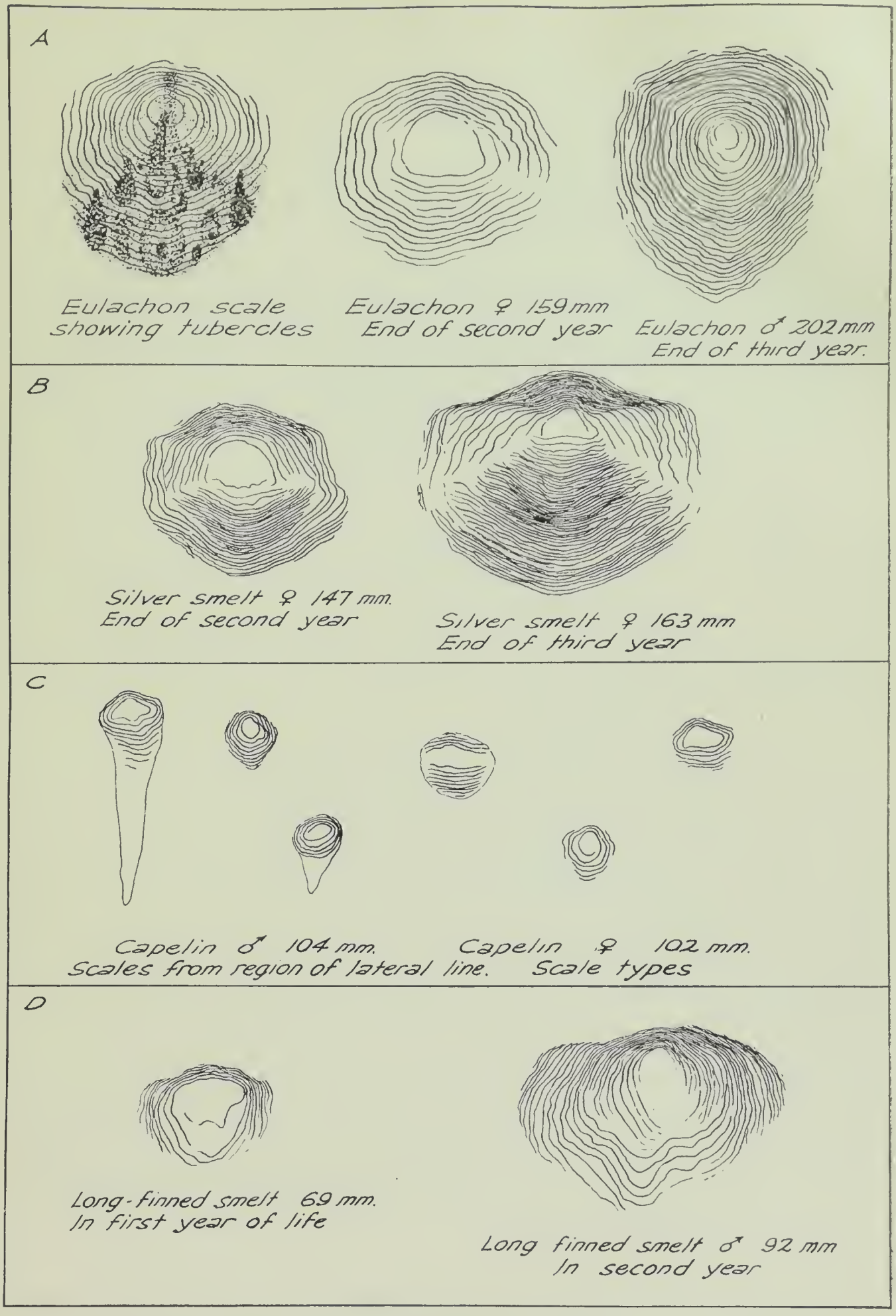

FIGURE 5. Scales from smelts found in British Columbia. A. Eulachon. B. Silver smelt. C. Capelin. D. Long-finned smelt.

Local Differences

Studies of vertebral number were made on eulachon runs to different localities in British Columbia with the following results.

Locality	Year	Number of vertebrae								No.	Mean	$S(x-\bar{x})^2$
		65	66	67	68	69	70	71	72			
Males												
Fraser river.....	1935	..	1	13	17	5	..	..	..	36	67.72	19.22
Fraser river.....	1939	..	6	62	101	21	3	1	..	194	67.773	118.02
Fraser river.....	1940	..	4	48	66	23	1	..	..	142	67.782	84.23
Fraser river.....	1941	..	5	45	81	15	..	..	..	146	67.726	69.05
Knight and Kingcome inlets....	1940	1	3	25	72	60	10	..	..	171	68.269	133.63
Rivers inlet.....	1940	..	1	16	45	20	6	..	1	89	68.202	76.36
Nass river.....	1940	..	..	6	49	56	7	1	..	119	68.563	61.30
Females												
Fraser river.....	1935	..	1	3	11	1	1	..	..	17	67.88	11.76
Fraser river.....	1939	..	..	24	71	18	..	..	..	113	67.947	41.68
Fraser river.....	1940	..	..	13	25	17	1	..	..	56	68.107	33.36
Fraser river.....	1941	..	10	69	102	27	1	..	..	209	67.713	122.78
Knight and Kingcome inlets....	1940	..	..	9	30	24	9	..	..	72	68.458	53.88
Rivers inlet.....	1940	..	..	..	...	..	..	..	..	0	....	....
Nass river.....	1940	..	1	6	23	30	5	..	..	65	68.492	44.25

The data show the Fraser river run to differ in average vertebral number from the runs to the more northern parts of the province, and it may be demonstrated that differences as great as those found could not occur by chance as often as once in 100 trials. This indicates that mixing between the runs to the Fraser and more northerly rivers cannot be extensive because, if it were, any differences in vertebral count would soon be eliminated. The males from the Nass river run also are distinct from the males taken in the central part of the province, but the females do not confirm the observation as being of certain significance. It is quite possible that largely independent runs exist in each of the major river systems. The tabulated vertebral counts also show that differences in average vertebral number too great to be caused by chance exist between the runs to the Fraser river in different years (females 1940 and 1941). The trenchancy of this fact is impaired by the existence of considerable differences between different samples from the same sex, year, and river system, but in no case (out of 10 possible comparisons) is the difference statistically significant or so great as that referred to above.

Size and Age

The eulachon is the largest of British Columbia smelts, being said to reach a length of about 12 in. although the collections studied included none much

over 8 in. in standard length (equal to about 9 in. to the fork of the tail). Fraser river eulachon vary considerably in length (fig. 8) and average between 6 and 7 in.

Studies of both scales and otoliths of eulachons show annuli which indicate most of the spawning fish to be completing their second year of life while a few are at the end of their third year. This is corroborated by the fact that the numbers of fish in the various size groups for a given sample, e.g. the run of 1941 in the Fraser river (fig. 8), give when plotted a curve with two humps or modes, indicating that the fish are partially divisible into large and small ones, the latter being more numerous.

In general, for the spawning fish, the outer edges of each scale were found to be absorbed so that the margin presented a characteristic clear irregular edge. A permanent record of this, known as a spawning mark, should, to judge from knowledge of other fishes, remain on the scales if the fish survives spawning and

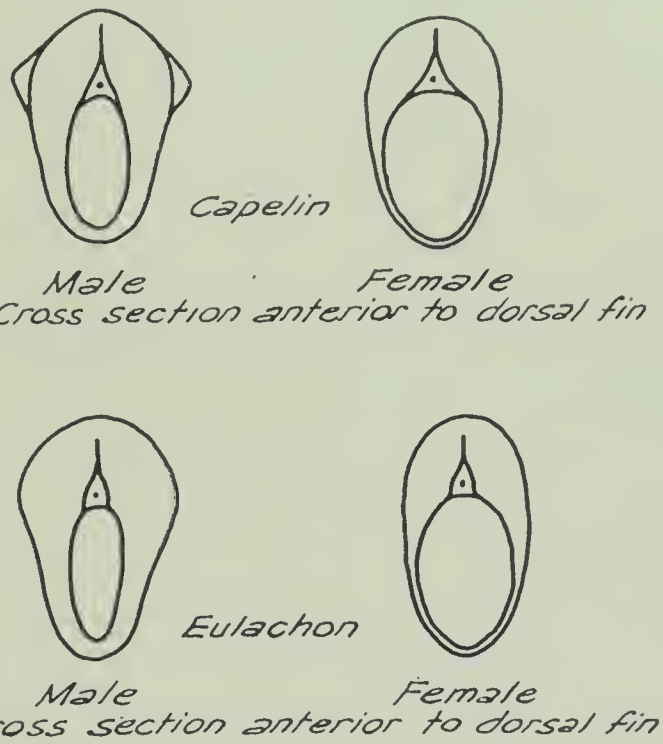

FIGURE 6. Cross sections through abdominal portion of male and female eulachon and capelin.

resumes growth. The eulachon scales, however, showed no evidence of such a spawning mark at the end of the first year of life, and in those fish which had completed three years of growth, very few showed evidence of a spawning mark at the end of the second year. It was concluded, therefore, that few, if any, of the fish had spawned in a previous year. This conclusion is in keeping with the observation that many dead eulachon are found in the rivers at spawning time and it is believed that in most, if not all, cases the eulachon spawns but once at the end of its second or third year and dies soon afterward.

THE SPAWNING RUN

The spawning migration lasts from the middle of March to the middle of May. The time of appearance is fairly constant from year to year in each

locality and the runs are apparently of progressively shorter duration from south to north. The first appearance of eulachon in the Fraser river is heralded by a downstream movement of the gulls which later follow the fish up the river on their migration. At first males greatly predominate but, although in general males appear to be more numerous, females may actually predominate at the last, as the following records show.

Fraser river-1939				Fraser river-1941			
Date	Males	Females	% Males	Date	Males	Females	% Males
April 12..	115	47	71	April 4...	123	27	82
April 24..	70	29	71	April 17..	28	22	56
May 19...	9	37	20	May 8...	31	171	15

Spawning and Early Development

The spawning act has not been seen. It evidently takes place in rather limited areas in the Fraser river since dredgings taken over about 35 miles of

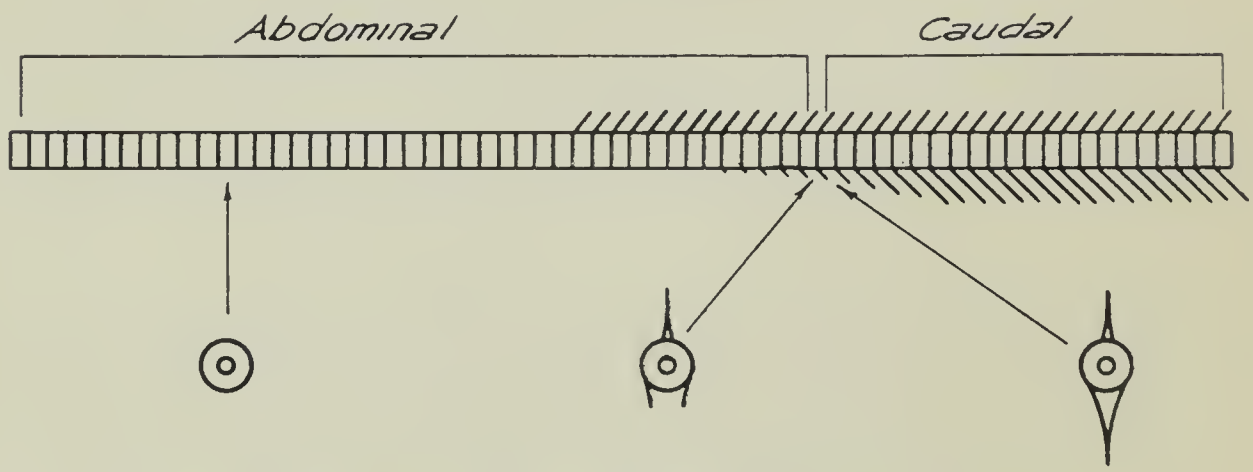

Figure 7. Differences between abdominal and caudal vertebrae.

river bottom between New Westminster and the mouth of the Sumas river near Chilliwack showed no evidence of spawning below Mission bridge, but above this point eggs were present in some of the samples. In all cases they were found attached to particles of coarse sand, and since the bottom deposits become increasingly finer in a downstream direction, it seems likely that the size of the sand grains may determine the limits of spawning. The heaviest concentration of eggs was found at a depth of approximately 25 ft. off Nikomen island, about 4 miles upriver from Mission. From here, eggs were found in varying numbers to a point about one mile above the mouth of the Sumas river, where the current becomes swifter and where investigation ceased. The area over which the spawning is known to take place, therefore, includes only about 8 miles of the river between Mission and Chilliwack.

The eggs show considerable irregularity in shape and variety in size. Both unspawned and spawned eggs have an average diameter between 0.03(3) and 0.04 in. after preservation in formalin. There are numerous oil globules in the yolk.

The egg becomes attached to sand grains in the river bottom in a characteristic way. The mature egg as it leaves the female has a double outer membrane. The outer layer is easily broken, separates from the inner covering, and becomes turned inside out. Since the two membranes remain attached over a small area, as shown in the illustration (fig. 9), a short stalk or peduncle is formed. The free edges of the broken membrane are extremely adhesive and readily become attached to particles of sand.

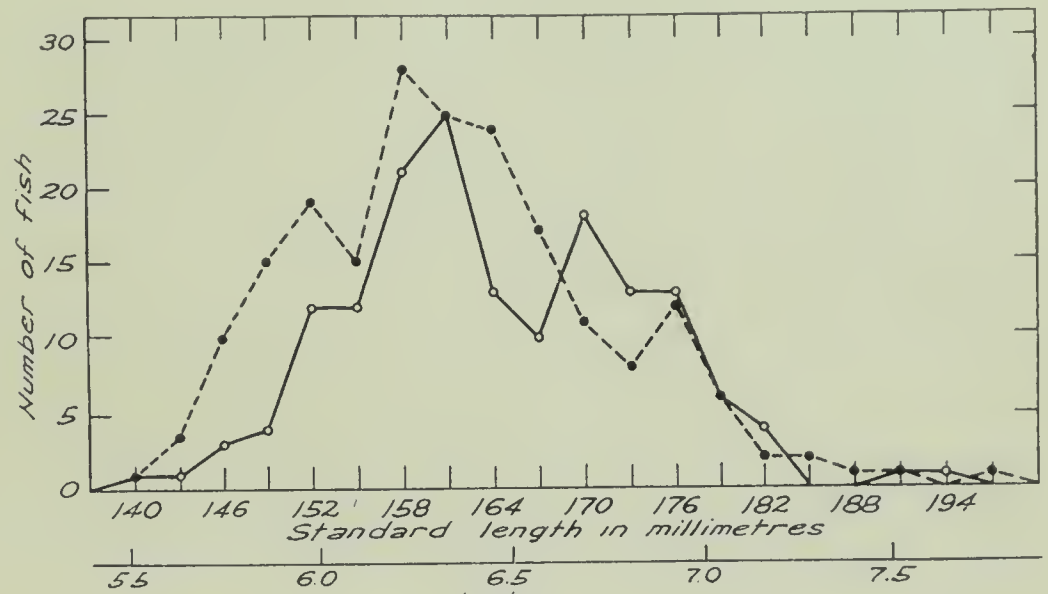

FIGURE 8. Length distribution of Fraser river eulachon in 1941. Solid line,—males. Broken line,—females.

The newly hatched young are slender, transparent little fish with rather small eyes and the yolk sac placed farther back than is frequently the case in larval fish. They are almost completely outlined by dorsal and ventral fin folds which are continuous with the tail fin. The young fish are about 0.25 in. long. Being relatively feeble swimmers, they are apparently carried to sea soon after emerging from the egg. If in the main current of the Fraser river, the newly hatched larvae would drift from Mission to the sea (a distance of about 40 miles) in less than twenty-four hours.

FECUNDITY

The female eulachon produces between 17,000 and 40,000 eggs. The number produced is related to the size of the fish but evidently there is considerable variation otherwise as illustrated by the following data on Fraser river fish.

Standard length (mm.)	(in.)	Eggs (no.)	Standard length (mm.)	(in.)	Eggs (no.)
145	5.71	17,300	175	6.89	36,600
145	5.71	17,600	179	7.05	28,600
158	6.22	32,500	182	7.17	36,200
159	6.26	20,600	184	7.24	31,600
171	6.73	32,300	185	7.28	39,600

A female eulachon of average size may be considered as producing about 25,000 eggs. Apparently only one batch of eggs is matured and spawned during the season (fig. 10).

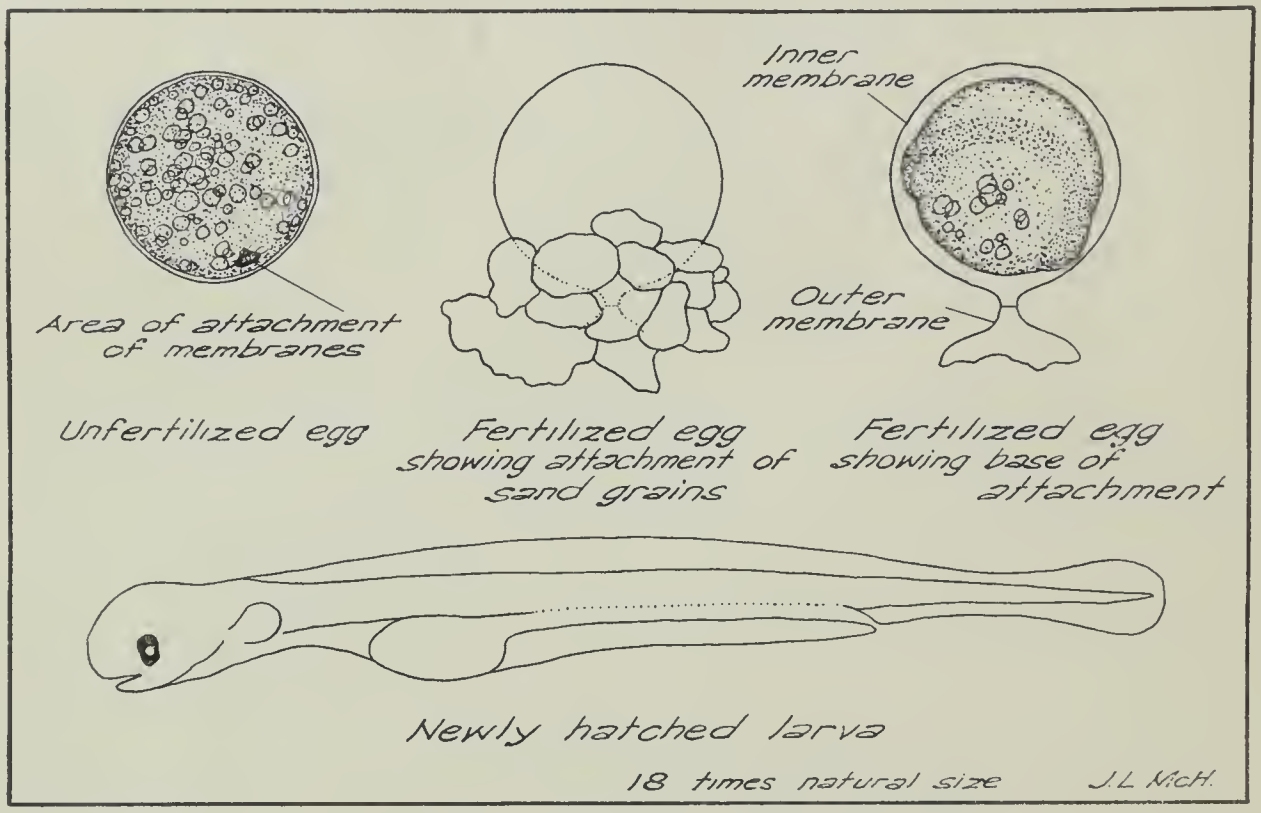

FIGURE 9. Eggs and larva of eulachon.

MARINE LIFE-HISTORY

Little is known of the life in salt water since once the larvae leave the river all trace of them is lost. A few well grown specimens are taken in trawls or seines, or are found in the stomachs of salmon or seals far from the spawning rivers. The food of such specimens as have been taken in Barkley sound and off the islands in the strait of Georgia consisted entirely of euphausiids—small shrimp-like animals which are abundant in British Columbia waters. No food is found in the stomachs of specimens taken in fresh water.

FOOD FOR OTHER ANIMALS

Eulachon are important locally as an intermediate step in the food chain between the small shrimp-like forms and the larger fish, marine mammals, etc.

D. S. Jordan in "*Fishes*" (*D. Appleton and Co., New York, 1925*) states that "even the stomachs of the sturgeons are often found full" of eulachon, and C. W. Stoddart in "*Over the Rocky Mountains to Alaska*" (*Herder, St. Louis, 1899*) says "The halibut, the cod, the porpoise and the finback whale had followed the oolachans out of the deep". Also C. M. Scammon (*The marine mammals of the north-western coast of North America, John H. Carmany and Company, San Francisco, 1874*) says, "During the early spring months the

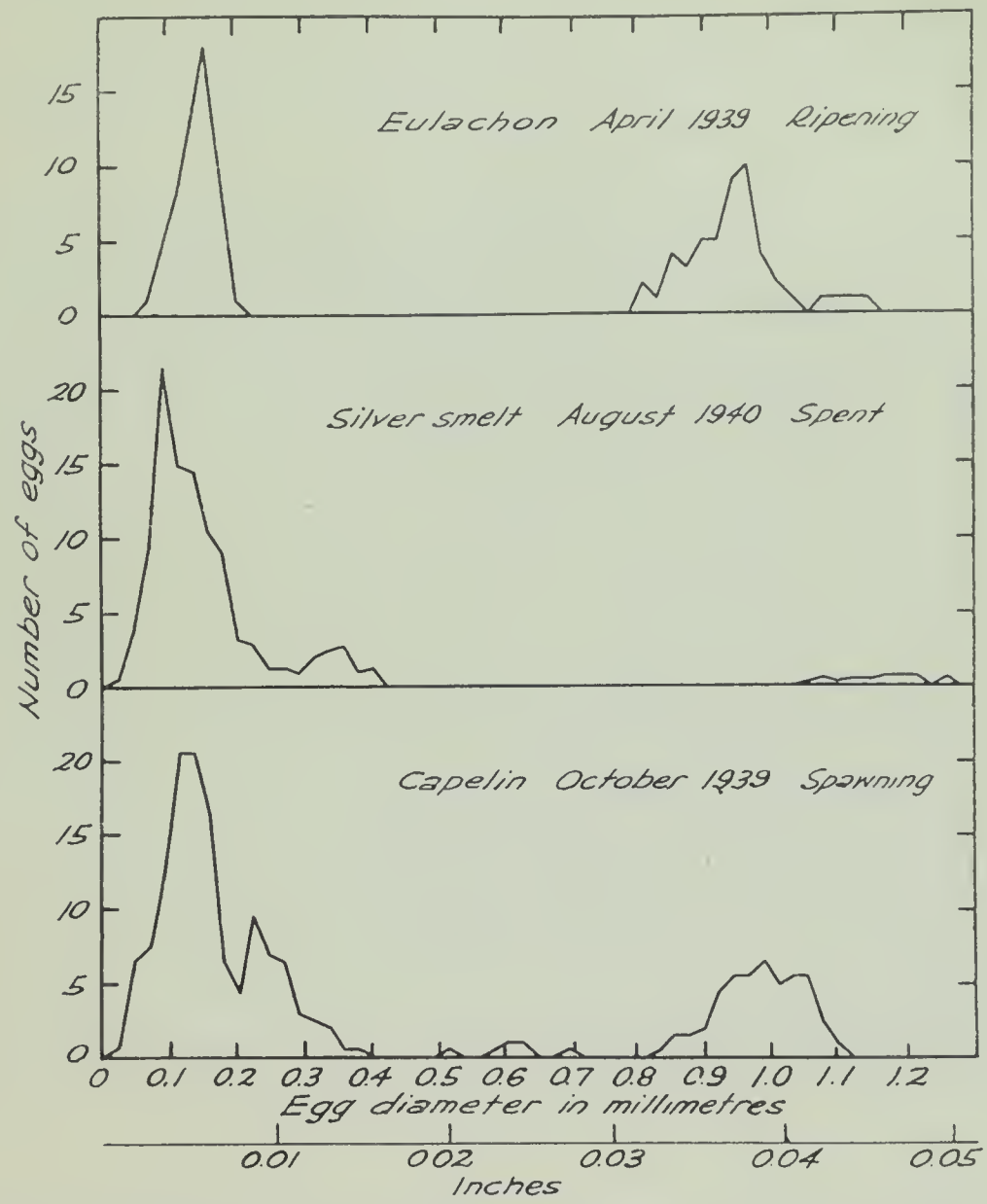

FIGURE 10. Distribution of egg diameters in eulachon, silver smelt, and capelin.

oulacon literally choke the mouth of the Nass, and here the seals and porpoises congregate to fill themselves to repletion from the myriads of those minnows; and, in turn, in obedience to the laws of nature, the Orcas (killer whales, locally called blackfish) are found here, pursuing and devouring the enemies of the 'small fish'." Sea lions are reported as having been sufficiently numerous to constitute a menace to native fishermen during the spawning migration, and there can be but little reasonable doubt that they were feeding on the eulachon.

Spring salmon and fur seals feed on eulachon as has been shown by studies carried out at the Pacific Biological Station.

Commercial Uses

The eulachon has two principal commercial uses—as a table delicacy, and as food for fur-bearing animals. As a table fish it is generally prized as a source of variety, and some gourmets consider that for flavour it ranks very highly among all American food fishes.

The commercial fishery is carried out in the river by drift gill nets of 1 to 1½ in. stretched mesh. A catch of 70 lb. of fish by 100 sq. fm. of net in an hour approximates average fishing in the Fraser river.

The only important commercial fishery at present is in the Fraser river. As the annual reports of the Department of Fisheries show, the eulachon was first handled commercially on the Nass river in 1877 with the object of manufacturing the oil for export. The product found such a ready sale among the local Indians, however, that none remained for export. Some oil was shipped to England during the first few years, but the hope of a large export market was never realized.

Later a considerable production of the salted and smoked product was developed, chiefly on the Nass, but gradually becoming of increasing importance in other localities. This development, according to the records, reached its peak about the year 1903, when the total production for the province was 4,070 bbl. salted, 45,200 lb. smoked, and over 1,000,000 lb. fresh. This represented a total value of $96,436. and the fishery at this time stood in fifth place among the fisheries of British Columbia. In 1912 the eulachon was still in fifth place with a value of $78,950. but subsequently the recorded catch and value dropped off rapidly, until at the present time the fishery is of relatively minor importance (fig. 11).

Importance to Native Indians

In the days before the arrival of the white men, thousands of Indians from northern British Columbia were accustomed to gather at the Nass river in the spring for the eulachon fishing. To many of these tribes, the river was important because of its eulachon fishery, and the Tlingits of southeastern Alaska gave it the name Nass, meaning "food depot".

As an article of food, the eulachon was of great importance to the Indians, chiefly because of the grease which could be extracted from it. The use of this grease or "kleena" was not confined to the coast tribes, but it was also a common food of the people of the interior, who would travel great distances to obtain their supply. It thus became an article of barter, and gave rise to the famous "grease trails", which roughly follow the courses of the great northern rivers. It was down the grease trail which followed the Bella Coola river to the sea that

Alexander Mackenzie travelled in 1793 to become the first white man to cross the American continent north of Mexico.

Those who may be interested in the methods used by the Indians in catching and processing these fish (fig. 11) should consult vol. 1 of J. K. Lord's "*The naturalist in Vancouver island and British Columbia*," (*Richard Bentley, London, 1866.*)

Condition of the Fishery

The production of the eulachon fishery as shown by Dominion Fisheries reports and catch figures is highly erratic (fig. 12). Part of the irregularity results from changes being made, especially in the early days, in the methods of

Figure 11. Eulachons drying out-of-doors at an Indian fishing camp on the Nass river.

recording the statistics. A considerable proportion of the catch is taken by Indians and local residents for personal consumption and at one time, but not recently, it was the practice to estimate this portion of the catch for inclusion with the records. Various economic considerations also affect the demand for eulachons. At first, ease of capture was probably the deciding factor in its importance, but as the knowledge of other species increased and methods of fishing improved, the eulachon market deteriorated. It is probable that at all times the demands of the small local markets rather than the supply of fish have dictated the size of the catch at the peak of the run.

Not all of the fluctuations and decline in the catch are the result of economic factors or the methods of recording the statistics, as is to be seen from the reports of the Department of Fisheries. The fishing effort must have been large enough in some years to suggest the possibility of over-fishing, since in 1881 it was stated that five thousand members of the Tsimpsyan tribe moved annually to the Nass for the eulachon fishing, and these large numbers are confirmed by various authors. As early as 1885 a failure in the eulachon run at Port Essington was reported, and in 1887 it was urged that protective measures be considered. The report for the following year mentions that the species appeared to be decreasing in the Fraser, and also that the methods used by the Indians on the

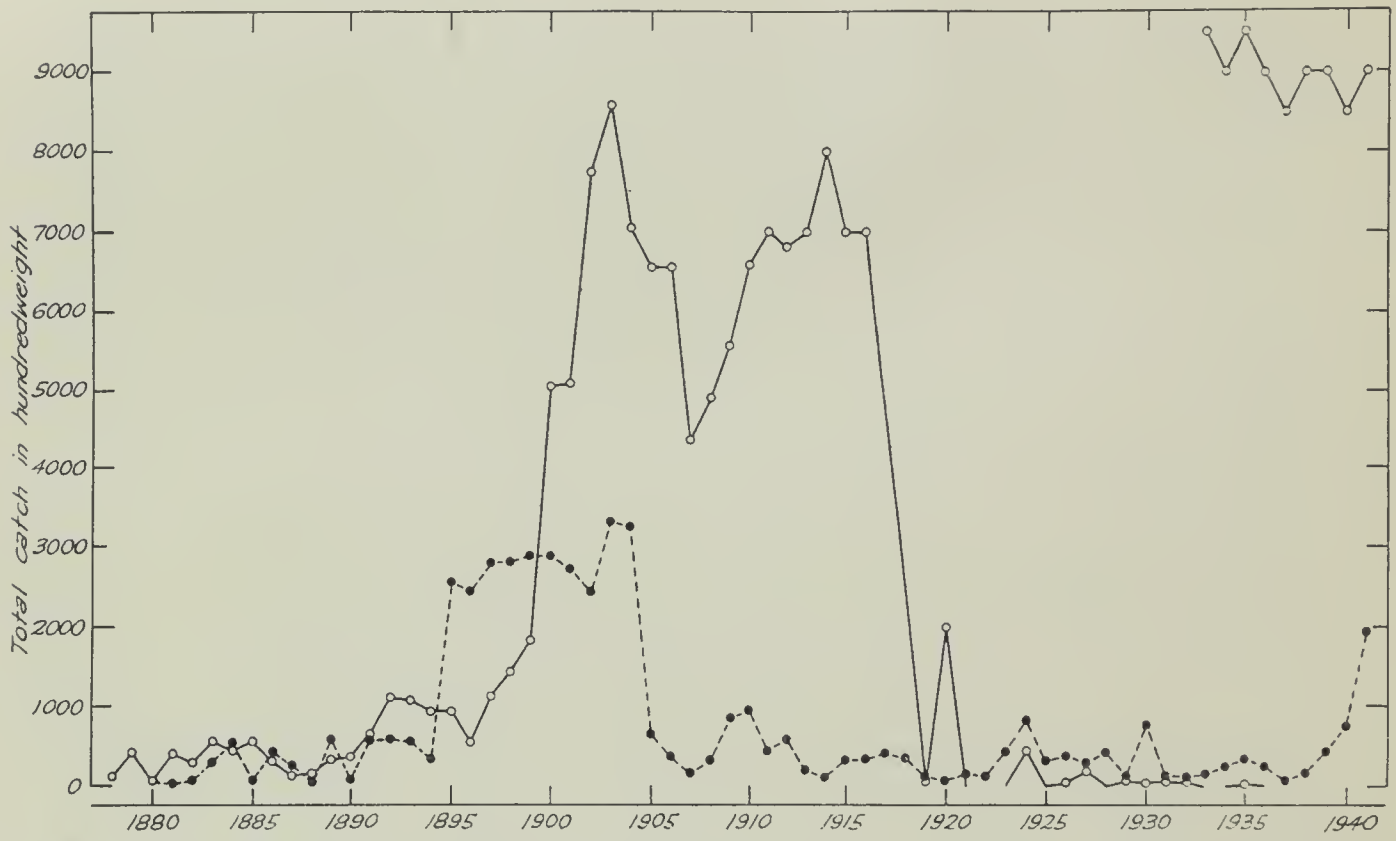

FIGURE 12. Eulachon catch statistics. Solid line,—Nass river. Broken line,—Fraser river. The solid line in the upper right of the diagram indicates estimates of the Indian take in the Nass. In recent years this part of the fishery has not been recorded with the commercial statistics.

Nass for extracting the oil were very wasteful. This waste is emphasized several times in later reports. Again, in 1890 the runs were light on both the Fraser and the Nass. For the most part there is no evidence that permanent decreases resulted from the fluctuations noted and it would appear that in many cases the fluctuations have been due to natural causes. The introduction of a scientifically designed method for the collection of statistics during 1941 and ensuing seasons is expected to provide definite information on trends in abundance.

SILVER SMELT

Names

The silver smelt or surf smelt is *the* smelt of the fresh fish markets of British Columbia. Scientifically it is designated as *Hypomesus pretiosus* (Girard). The first of the Latin names means "below the middle" and refers to the pelvic fins' position behind the dorsal fin. *Pretiosus* means precious and refers to the delicate flavour.

Description

The silver smelt (figs. 1B and 13) is characterized by a small mouth with the maxillary bone not quite reaching the mid-point of the pupil of the eye. The teeth are firm and are not customarily lost at spawning time. The dorsal fin is slightly in front of the origin of the pelvic fins. There are 66 to 76 scale rows along the lateral line and the scales come off very readily. There is a prominent longitudinal bar on the side. (In fresh specimens this bar is silvery and mirror-like. It is caused by the appearance of the guanin crystals deposited in the thin translucent skin over the dark mass of the *lateralis superficialis*

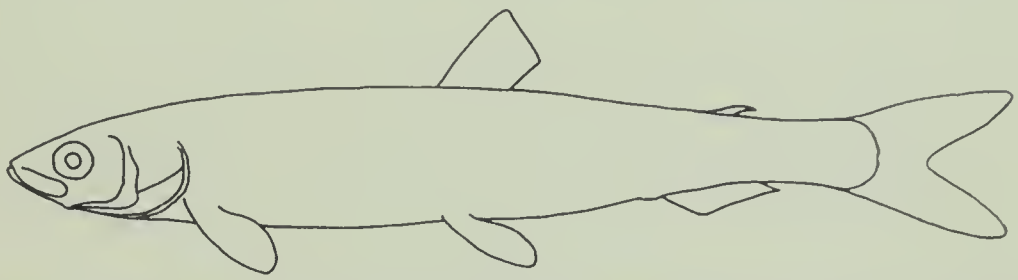

Figure 13. Female silver smelt. Note small mouth and adipose fin and the position of the dorsal fin in relation to the pelvic fins.

muscle in contrast to its appearance over the lighter and less opaque *lateralis profundis* muscle. However, when the guanin is removed by preservation in formalin the colour of the muscle becomes apparent as a dark brown longitudinal band.)

The sexes may be distinguished at spawning time by external appearance but the differences are less marked in the silver smelt than in any other British Columbia smelt. The female is somewhat larger than the male on the average, and the back is bright green in contrast to that of the browner male. The belly of the female is rounded in form and silvery white in colour on the sides whereas that of the male is less full in contour and golden in colour. Further, the males are said to be distinguishable by the presence of numerous very fine tubercles on the sides, heads, and fins.

Distribution

The range of the silver smelt extends from southern Alaska to central California. In British Columbia most of the reported localities are in and around the southern part of the strait of Georgia and Whiterock near the United

States boundary. The species is recorded as present in the vicinities of Rivers and Smith inlets and as apparently abundant around the mouth of the Skeena river. The fact that the species is recorded as most abundant on the part of the coast which is most densely populated leads to doubt as to whether the recorded distribution may not depend to a large extent upon opportunities for observation.

Local Differences

Vertebral counts show that the fish on different fishing grounds belong to different populations.

Locality	Date	Number of vertebrae								No.	Mean	$S(x-\bar{x})^2$
		62	63	64	65	66	67	68	69			
Whiterock.....	July 8/40	..	..	6	17	20	4	4	..	51	65.67	55.33
Whiterock.....	Aug. 20/40	..	..	10	37	32	15	1	2	97	65.65	102.08
Pt. Grey.....	Aug. 20/40	1	..	8	32	41	9	3	1	95	65.64	97.83
Off Skeena.....	July —/40	..	..	1	29	32	20	3	3	88	66.05	91.82
Pt. Grey.....	July —/41	1	..	10	66	78	27	5	1	188	66.73	164.70

Calculations based on these data show that the differences between the average vertebral numbers of silver smelt taken at the mouth of the Skeena river and those for fish caught in areas in southern British Columbia could occur by chance only once in 35 or more trials. It is concluded, accordingly, that extensive mixing does not take place. It is probable, moreover, that the populations which spawn at widely different times in southern British Columbia are distinct from one another, and that further knowledge will demonstrate in southern British Columbia a series of more or less distinct populations such as have been shown to exist in Puget sound.

Size and Age

Silver smelt have been reported to be about a foot long but the fish which have been measured in British Columbia or in the State of Washington in recent years are considerably shorter. The largest specimen encountered in British Columbia was less than 7¼ in. in length and the average length of fish encountered in the commercial runs is about 5 1/3 in. The length distributions of 5 British Columbia samples (fig. 14) show: (1) the length spread in each sample is considerable (more than 30%); (2) samples taken in different places or at different times at the same place differ from one another; (3) male silver smelt are shorter than females; and (4) the forms of the figures with one possible exception suggest that more than one year-class is represented in each sample, and this is especially true of the 1940 Point Grey sample.

The ages of silver smelt may be determined by examining the scales (fig. 5B) which are peculiar in that they are formed so late in the first year that no annulus is formed during the first winter. Accordingly, a spawning fish with one check on its scale is just completing the second year of its life. Such is the usual condition found on examining scales of silver smelt in British Columbia. Some

spawning fish have two checks on the scales and may be assumed to be completing the third year of life. Some silver smelt may well spawn at the end of the first year as has been indicated for Puget sound fish. First year spawning may account for the group of very small fish encountered in the Point Grey sample from which no scales were examined. There is evidence, as yet inconclusive, that silver smelt die after completing their first season's spawning.

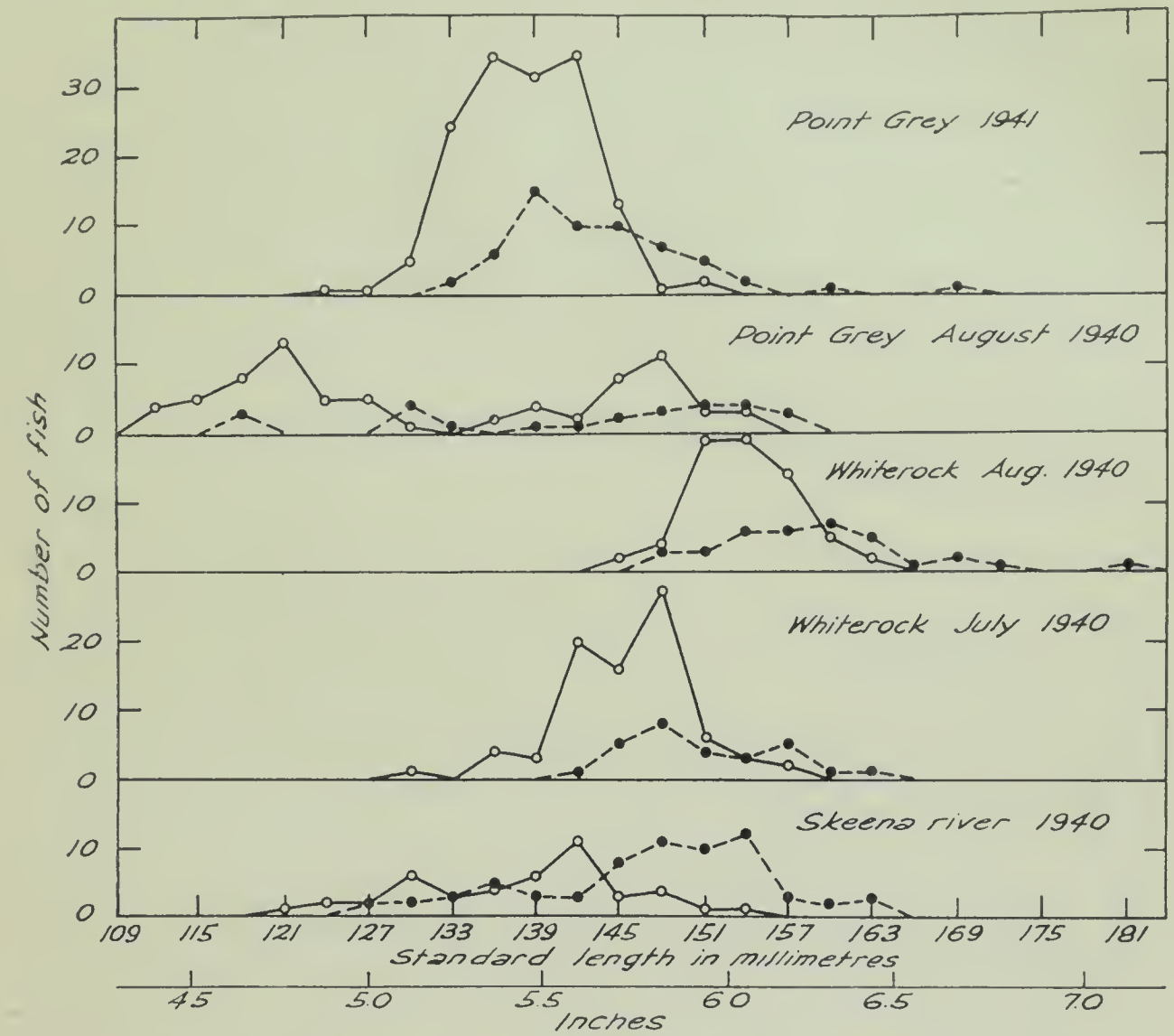

FIGURE 14. Length distributions in samples of silver smelt from various localities. Males,—solid line. Females,—broken line.

SPAWNING

Silver smelt spawn under a great variety of conditions and in most months of the year. Summer spawnings take place both on exposed beaches and at the heads of sheltered bays. In the former situation the surf acts so that eggs which are attached to gravel of appropriate size for anchors are covered by a layer of sand which prevents undue drying out at low tide. Summer spawnings in sheltered areas are typically on shaded beaches, where temperatures in the gravel during daylight low tides are demonstrably lower than on unshaded beaches, or on beaches with northern exposures. Usually the fish spawn where there is a certain amount of fresh water seepage through the fine gravel to which the eggs

adhere. Winter spawnings take place over gravel with this seepage which prevents smothering of the eggs, but they are recorded from unshaded beaches as well as shaded ones. Winter spawnings are not recorded from beaches exposed to ocean surf. It will be seen that under each set of spawning conditions there is evidence of adaptation which assures that the eggs are both sufficiently aerated and that they are kept moist while the tide is out.

The first indications of spawning are in the play of a few fish off the spawning grounds. In some places it has been observed that only male or female fish will be in a school and that the schools of female fish are the first to appear. This segregation of the sexes leads to very erratic estimates of sex ratios as illustrated in the following data for five British Columbia samples.

Locality	Date	Males	Females	% Males
Whiterock	July 8/40	82	28	75
Whiterock	Aug. 20/40	66	35	65
Pt. Grey	Aug. 20/40	74	26	74
Off Skeena	July —/40	44	67	40
Pt. Grey	July —/41	146	57	72
Average				65

The total percentage of males is close to that observed as an average for Puget sound silver smelt (66%), but the estimates of the proportions of males is open to question, since the fishing method is often somewhat selective (some of the males escape through the nets), and it has been found that off one beach at least the proportion of males decreases with the advance of the spawning season.

In general, spawning takes place at high tide and on the falling tide, although sometimes it may begin as early as 1½ hr. before high water. Most intense spawnings seem to take place on days when high water occurs in the late afternoon. In Puget sound, days which are comparatively calm appear to be preferred for spawning; however, as pointed out, populations are known which spawn on beaches exposed to ocean surf.

The behaviour of the males and the females in the spawning act has been described by M. B. Schaeffer (*Contributions to the life history of the surf smelt (Hypomesus pretiosus) in Puget sound. Washington State Dept. Fisheries, Biol. Rep. 35B, 1936*).

Development and Hatching of Eggs

Most of the eggs are found in the top few inches of sand and gravel between the 7- and 11-ft. tide levels. They are small, almost transparent, yellowish, with numerous small oil globules in the yolk, and they are so adhesive that they immediately stick to any gravel with which they come in contact. The mechanism accomplishing the fixation of the egg as described is very similar to that

observed in the case of the eulachon and recorded in the section dealing with it. When summer temperatures prevail during the incubation period the eggs may hatch in as little as 10 or 11 days but autumn and winter spawned eggs take much longer to be ready for hatching. The newly hatched young are about 0.12(5) in. long—very slender, and very active.

Fecundity

The spawning of a single batch of eggs may last over several days and during that time the female silver smelt will produce from 2,500 to 37,000 eggs, depending upon the size of the fish. Silver smelt of the sizes most commonly encountered usually produce between 15,000 and 20,000 eggs. Studies of the ovaries have shown that these fish spawn several such batches during a spawning season. Besides the mature eggs about to be spawned (right hand side in fig. 10), a group of minute eggs (left hand side) is beginning to be differentiated from the general mass of potential eggs. This group represents the eggs to be shed at the spawning following the one which was imminent at the time the fish was captured. The protracted spawning season fits in well with the idea of multiple spawnings by individual fish, but so far it is not possible to say how many spawnings an individual fish may participate in during a season.

Life-History

Little information is at hand concerning the life-history of silver smelt between the disappearance of the newly hatched larvae and the return to the spawning grounds of the maturing fish. Occasional specimens are taken in beach seining operations but there is no reason to believe that the main population of immature fish has ever been encountered.

In general little food is found in the stomachs of fish near the spawning grounds, but it would appear that ripe fish will take food, since the Skeena river sample was obtained by attracting the smelt with roe prior to capturing them with a dip net. The only other stomachs of feeding fish encountered contained euphausiids, shrimp larvae, amphipods, and one specimen of a marine worm, *Eteone longa* (Fabricus), known to live in clean sand. It would appear that in general the normal food is crustacean.

Economic Importance

The commercial fishery for silver smelt is carried on largely by beach seines in the southern part of the province. On some beaches the catch is considerably augmented by people fishing for amusement with home made dip nets, garden rakes, and even canary cages. It is probable that the official statistics for annual catch (fig. 15) fail to take into account a large part or all of the very substantial recreational catch.

Silver smelt have been found occasionally in the stomachs of spring salmon. They do not appear to be a favoured food of predator fish, however, since they are reported to be not effective as bait for ling cod.

Use By Indians

No descriptions have been encountered of the early use of silver smelt by British Columbia Indians, but they may have been so used since there is evidence to indicate that they were taken by the neighbouring tribes of the Olympic peninsula. (*J. G. Swan. The surf smelt of the northwest coast and the method of taking them by the Quillehute Indians, west coast of Washington territory. Proc. U.S. Nat. Mus., 1880, III, 1881.*)

Conditions of the Fishery

The trend of catches (fig. 15) is definitely down. As there is no reason to believe that the decline in total catch has been due to any falling off in demand it seems likely that the fish themselves may be becoming less abundant, and a similar trend for the Puget sound fishery suggests that a general decline has taken place over all of the more densely populated part of the range. It is sug-

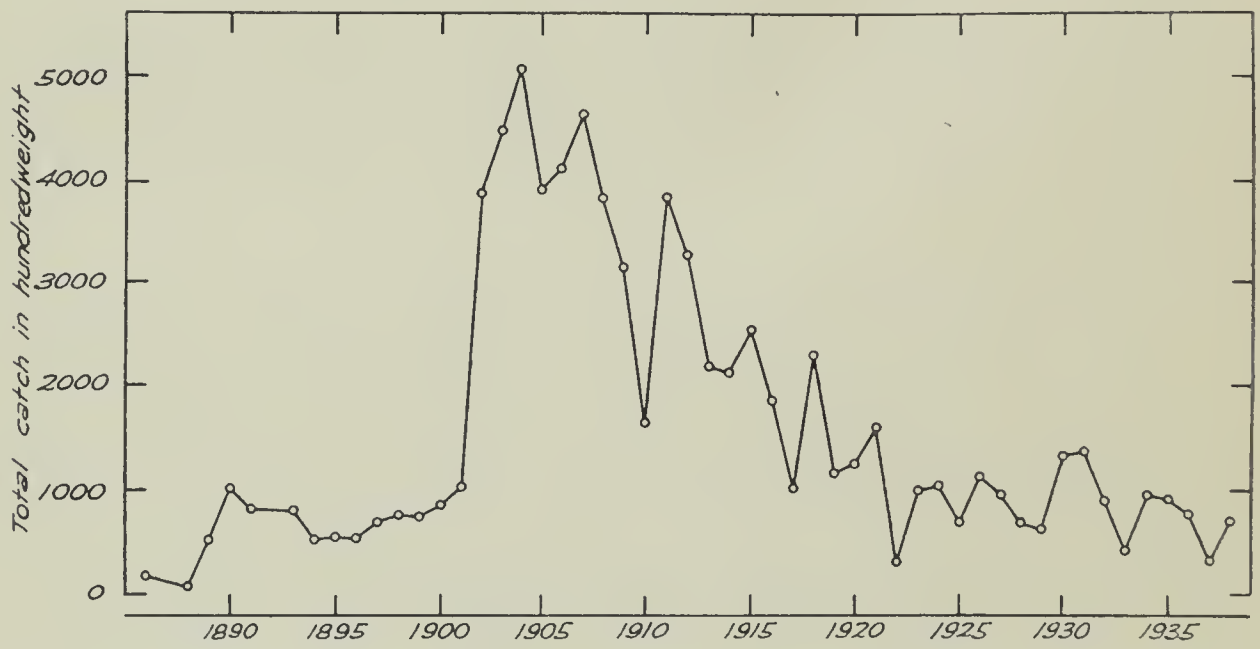

Figure 15. Silver smelt catch statistics.

gested in view of the observations on the relationship between shade on beaches and the use of the beaches for summer spawning that the encroachments of civilization may be reducing the area of the natural spawning habitat. Pending fuller investigation, regulations preventing fishing during the first part of the spawning run as enforced at the entrance to Burrard inlet appear to be satisfactory. There is evidence for believing that protection of this kind has been efficacious in the case of a major Puget sound silver smelt fishery.

CAPELIN

Names

The capelin, frequently misnamed smelt, has long been known on the British Columbia coast, and until recently was considered as identical with the capelin

of the north Atlantic which is also called caplin, capelan, or lodde. Certain differences have since been found, and the species was redescribed as *Mallotus catervarius* (Pennant) by Schultz in 1937. The first name refers to the rough "hairy" appearance along the sides of the spawning males and the specific name draws attention to the schooling habits.

Description

The mouth of the capelin (figs. 1C, 16 and 17) is small or intermediate in size so that the maxillary bone does not reach as far as the mid-point of the eye. The scales are small; between 175 and 209 rows, or an average of approximately 189 rows are to be found along the lateral line. The teeth are small and are present in the spawning fish.

The sexes differ considerably in form and appearance, especially at spawning time. The breeding males are characterized by a remarkable and distinct ridge along the lateral line. This is formed by an elongation of the posterior edge of the scales in this region (fig. 5C), and the sharp ridge thus formed causes the males to be almost diamond shaped in cross section (fig. 6). In addition, the muscular portion of the body in the male is much more robust, and the fins, with the exception of the adipose, are longer and broader than in the female (figs. 16 and 17). In the spawning males the pectoral fins bear membranous ridges on the anterior, and tubercles on the posterior surface of the rays, and the first 10 to 12 rays of the anal fin are much enlarged, particularly in their distal portion. The males at spawning time are also provided with tubercles in the head region.

It has been shown on the basis of collections made between 1930 and 1936 and in 1939 and 1940 near Nanaimo that sexual dimorphism extends even to vertebral number, a condition which is unusual among fishes.

Year	Number of vertebrae									Mean	$S(x - \bar{x})^2$
	62	63	64	65	66	67	68	69	70		
Males											
1930-36	..	3	29	171	173	50	14	1	1	65.65	392.0
1939-40	2	3	42	122	136	48	10	..	..	65.57	370.8
Total	2	6	71	293	309	98	24	1	1	65.62	764.2
Females											
1930-36	..	8	36	70	36	15	1	1	..	65.13	186.4
1939-40	..	..	9	16	15	2	..	..	..	65.24	29.6
Total	..	8	45	86	51	17	1	1	..	65.15	216.4

Combining all the data, the males are found to exceed the females by a count of 0.47, and this is statistically highly significant as the difference could not have happened by chance as often as once in 100 times (P is much less than

0.01). Counts made on a small sample of capelin showed that although the males had a higher total number of vertebrae than the females, the reverse was true in the case of the abdominal vertebrae, and that therefore the difference between the sexes in the number of caudal vertebrae was considerably larger (see fig. 6 for their characters), as follows:

	Males	Females	Difference
Average total count.....	65.32	65.13	+ 0.19
Average abdominal count.....	42.76	43.22	− 0.46
Average caudal count.....	22.56	21.91	+ 0.65

The difference in caudal count is statistically highly significant (P much less than 0.01). The few species of fish in which differences in vertebral number have been demonstrated between males and females show the difference in the abdominal region, the females having more abdominal vertebrae, presumably to provide for carrying more eggs. It is interesting that this holds for the capelin, even though the difference in total count is in the opposite direction.

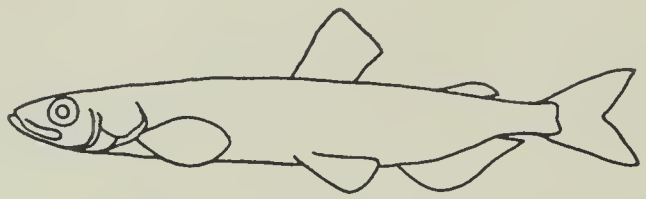

FIGURE 16. Male capelin. Note small mouth and large adipose fin.

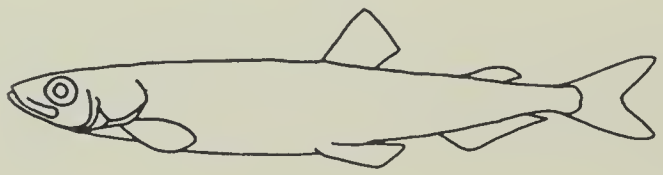

FIGURE 17. Female capelin. Note more tapered form and smaller fins (especially those on under side of body).

DISTRIBUTION

The capelin is an arctic species with its centre of abundance in the Bering sea or Arctic ocean. The most southerly record of distribution is at Bentinck island, near Victoria, and the most southerly known breeding grounds are near Ladysmith on Vancouver island. Several isolated spawning grounds are known in the central part of the strait of Georgia, or its inlets such as the north shore of Burrard inlet. Records of its occurrence on other parts of the coast are rather scattered—large numbers were observed in February in the surf along the east coast of Graham island in the Queen Charlottes about the year 1924 and they have been recorded from the entrance to Naden harbour. A few specimens have been recorded from Prince Rupert harbour and spawnings have been reported from Ryan point and the Lucy islands. The species is generally not well known on the British Columbia coast, and, except for one or two localities, occurs in

rather small numbers. It may be that the relative scarcity of capelin in British Columbia is related to the fact that the the southern limit of the species' distribution in the east Pacific is in southern British Columbia. The fact that most of the records are in well settled parts of the coast suggests that the recorded spawning areas do not represent all or nearly all of the total spawning grounds.

Size, Age, and Vertebral Number

No definite growth marks showing the age can be observed on the bones, and although the circuli on the scales are clear-cut, no evidence of growth checks was observed in any case (fig. 5C). Since the individuals in a spawning population are very uniform in size, it is probable that most, if not all, belong in a single year class, and according to the scales are at the end of their first year. In average standard length the males are about 4.17 in. (106 mm.) and the females 3.90 in. (99 mm.). This is somewhat greater than the length of the Newfoundland capelin at the end of the first year (2.36 to 3.15 in. or 60 to 80 mm.), but considerably smaller than at the end of the second year (males 5.32 to 5.91 in. or 135 to 150 mm.; females 4.13 to 4.92 in. or 105 to 125 mm.). This would indicate a rate of growth for the Pacific capelin which is somewhat greater than that of the Atlantic species.

Samples of spawning capelin were taken occasionally from 1930 to 1940 inclusive, and examined for length, sex, and vertebral number.

Year	Locality	Number of fish		Average standard length				Number of vertebrae	
		♂	♀	♂ (mm.)	♂ (in.)	♀ (mm.)	♀ (in.)	♂	♀
1930	Departure bay...	99	41	105	4.13	101	3.98	65.76	65.05
1932	Departure bay...	31	15	106	4.17	99	3.54	65.50	65.13
1934	Departure bay...	359	34	105	4.13	100	3.94	65.59	65.24
1936	Hammond bay...	209	82	105	4.13	99	3.54	65.72	65.11
1939	Lantzville.....	384	58	106	4.17	99	3.54	65.71	....
1939	Hammond bay...	149	6	107	4.21	...	...	65.70	....
1940	Departure bay...	41	37	110	4.33	105	4.13	65.32	65.13
1940	Hammond bay...	656	8	109	4.29	...	...	65.39	....

In average length the samples were very uniform, with the exception of those taken in 1940, when both males and females averaged larger by 0.12 and 0.24 in. (3 and 6 mm.) respectively. For all years combined except 1940 the males ranged from 3.70 to 4.53 in. (94 to 115 mm.) and the females from 3.54 to 4.41 in. (90 to 112 mm.), with means of 4.17 and 3.99 in. (106 and 99 mm.) respectively.

The data also show that mean vertebral number varies very little between localities in the same year. Statistical treatment of the data fails to show significant differences between Lantzville and Hammond bay in 1939 or between Hammond bay and Departure bay in 1940. However, considerable variation is found between year classes, as illustrated by the data for 1939 and 1940. The

latter year was warmer than average and growth rate was faster, which appears to be a natural consequence of higher temperatures.

Spawning and Early Development

At spawning time, capelin appear in schools of considerable size along the shores of gravelly beaches. Spawning takes place in various localities in the strait of Georgia during late September or the month of October. At this time of year water temperatures are in the neighbourhood of 50 or 55°F. Spawning takes place in the evening at high tide right at the water's edge. Pairing of males and females has been observed to some extent (the night spawning habit makes observation difficult) and there is probably a definite grouping of the sexes during the spawning act, as has been described for the Atlantic species. Males outnumber females about 7 to 1 in the surf but sex ratios in general are erratic.

Studies of the beach both during and after spawning indicate that a specific type of ground is selected. During spawning on certain beaches, considerable variation may be observed in the concentration of fish along the shore. This appears to be correlated with the nature of the beach surface, the fish tending to avoid both rocky and sandy patches. Later examination confirms this impression, the intensity of deposition being greatest where the particles are from 0.04 to 0.2 in. in diameter. A marked tendency is evident for the eggs to be attached to sharp corners and edges rather than to flat surfaces. This undoubtedly provides for free aeration during development. The eggs are extremely adhesive, and immediately become firmly cemented to the gravel. As spawning takes place at the water's edge and is most active at high tide, the eggs are concentrated in the intertidal zone with the maximum concentration found at about the 10 or 12 ft. tide level. On some beaches the eggs become buried to a depth of about 6 in. by the action of the waves. A quantitative study of the deposition of eggs at Hammond bay in October, 1939, showed that a minimum of 1,000,000 fish had spawned there including both sexes.

The eggs hatch in two or three weeks. The newly hatched capelin is a slender, almost transparent little fish between 1/5 and 1/4 in. long. The yolk sac, like that of the eulachon larva is well back and is small at hatching time. The vent too is situated farther back than in many species of young fish. There is a single row of prominent pigment spots along the base of the ventral fin fold from the yolk sac to the vent and the line is continued brokenly beyond these limits.

Fecundity

The average female capelin in southern British Columbia ripens approximately 4,600 eggs for a batch which may take several nights to be completely extruded. The number of eggs is related to some extent to the size of the fish but there is considerable individual variation as is shown by the following counts:

Standard length (mm.)	(in.)	Eggs (no.)	Standard length (mm.)	(in.)	Eggs (no.)
95	3.74	3020	102	4.02	4590
98	3.86	3840	103	4.06	3860
99	3.90	5250	103	4.06	6670
100	3.94	3550	104	4.09	3330
100	3.94	5940	108	4.25	5850

The size frequencies of the eggs (fig. 10) suggest that the mature capelin spawns more than one batch of eggs as there appears to be one group of small eggs becoming differentiated from the general mass which comprise the residual ovarian tissue after the ripe eggs are spawned out. It is not known at the present time whether any such second spawning occurs. It is possible that more or less nomad schools of capelin move around the southern part of the strait of Georgia spawning on suitable beaches as the eggs ripen. There is no racial evidence against such a belief but the only evidence in favour of such a supposition is the observations on the ovaries taken in conjunction with the lack of second spawnings occurring on the same beaches.

Life-History

Little is known of the deep-water phase of the life-history. The young fish very quickly disappear after hatching, and until they return as adults to spawn only occasional specimens are taken, and these generally from the stomachs of other species. Two individuals taken from salmon stomachs were found to have been feeding exclusively on euphausiids.

Economic Importance

The species is not sufficiently numerous to be of great economic importance in British Columbia waters. Studies of the food of spring salmon have shown that these valuable commercial fish occasionally make use of capelin as food. During the spawning run of capelin, dogfish are to be found in the vicinity evidently preying upon them but there is nothing to correspond to the condition connected with the Atlantic capelin where the inshore migrations of the cod and the capelin coincide very closely both as to time and distribution and where the commercial cod fishery is closely connected with the capelin movements.

There is no commercial fishery for capelin but the species is used to some extent for food by local residents during the spawning period. A certain amount of entertainment is provided due chiefly to the unusual spawning habit and to the novel methods of fishing adopted. At times, each wave breaking on the beach appears to be a mass of these fish, and quantities are taken by whatever means is convenient—buckets, improvised dip nets, common garden rakes, or even the bare hands serving as fishing implements. Lamps and flashlights are carried but these are to locate good fishing places rather than to lure the fish, which tend to be repelled by light.

Condition of Population

The runs fluctuate in intensity from year to year on the same beaches so that it is difficult to say whether they are being maintained. Moreover the irregular methods and unstable intensity of fishing make any estimate of changing abundance difficult. No marked trends have been reported. Although the annual capelin run contributes to the variety of existence on the seashore it is doubtful if the economic value of the species is sufficient to warrant fisheries regulation for its protection.

LONG-FINNED SMELT

Recognition

The long-finned smelt, *Spirinchus dilatus*, Schultz and Chapman, was first recognized scientifically in 1934, although it is probable that it was noticed by shrimp trawlers and silver smelt fishermen as "a different smelt" prior to that time.

Description

As suggested by the common name, one of the prominent features of this fish is the long paired fins—the pectoral fins reaching approximately to the bases

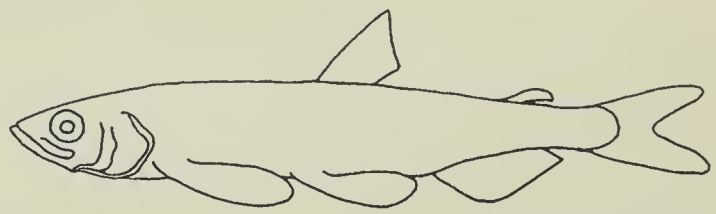

Figure 18. Immature long-finned smelt. Note large mouth and large size of pectoral and pelvic fins.

of the pelvic fins and the pelvic fins extending almost to the base of the anal fin (figs. 1D and 18). The mouth is large with the maxillary bone extending back well beyond the centre point of the pupil of the eye. The teeth are rather small and are not deciduous. There are about 63 (61 to 65) rows of scales in the lateral line. Spawning takes place in fresh water.

The name *dilatus* refers to the swollen condition of the three rows of scale pockets along the lateral line in the breeding males. This condition, however, is not present at other times of the year. At spawning time the males also differ from the females in the profuse fine black stippling, especially around the margins of the scales, along the back and above the lateral line; in the enlargement or swollen condition of certain fin rays; and in the presence of fine tubercles on the scales, and pectoral and pelvic fins.

Distribution

The long-finned smelt is limited in its distribution to Puget sound and the southern part of the strait of Georgia. In British Columbia it is known only from the Fraser river and its immediate vicinity.

Size and Age

Twenty-seven specimens taken in a shrimp trawl in Burrard inlet on March 2, 1934, were from 3.66 to 5.28 in. (93 to 134 mm.) in standard length, 6 males averaging 4.17 in. (106 mm.) and 21 females averaging 4.33 in. (110 mm.) in standard length. The sex organs of these fish were all immature, and the measurements of individual eggs gave no indications of any development in preparation for spawning. In view of this, it is interesting to note that in length range these fish appear to be larger than those encountered in the spawning run in Puget sound. Examination of the scales showed that one winter check was present, suggesting that these fish were in their second year of life (fig. 5D).

Life-History and Spawning

Since the long-finned smelt is not of common occurrence, its life-history is not well known. It spawns in fresh water and a male in breeding condition was captured in Harrison lake. However, actual spawning has not been observed. The young probably spend considerable time in fresh water before descending to the sea, as indicated by the capture of 4 specimens ranging in standard length from 2.40 to 2.83 in. (61 to 72 mm.) in the Fraser river at New Westminster. The scales of these fish bore no checks (fig. 5D) and it is concluded that they were in their first year. Since spawning apparently takes place in the autumn, the young fish probably do not form scales until the following spring, and therefore the first winter is not recorded on the scales. The food of the young fish consisted entirely of *Neomysis mercedis*, a shrimp-like form found only in fresh or brackish water. Eventually the small fish move down into the salt water. There, the diet is changed. The larger fish of those taken in Burrard inlet had been feeding on euphausiids, while the smaller individuals had eaten copepods and occasional Cumacea. These are all salt-water shrimp-like forms, the interesting point being that the two last named are of smaller size.

The long-finned smelt is of no economic importance in British Columbia.

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